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Analysis of Mine Fires for All U.S. Metal/Nonmetal Mining Categories, 1990–2001

Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH

Information Circular 9476

Analysis of Mine Fires for All U.S. Metal/Nonmetal Mining Categories,1990–2001

By Maria I. De Rosa

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
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CONTENTS

CONTENTS–Continued

ILLUSTRATIONS

TABLES

TABLES–Continued

TABLES–Continued

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

hr	hour(s)	st	short tons
min	minute(s)		

ANALYSIS OF MINE FIRES FOR ALL U.S. METAL/NONMETAL MINING CATEGORIES, 1990–2001

By Maria I. De Rosa[1]

ABSTRACT

This report analyzes mine fires for all U.S. underground and surface metal/nonmetal mining categories during 1990–2001 by state and six successive 2-year time periods. Injury risk rates are derived, and ignition source, methods of detection and suppression, and other variables are examined. Fires involving contractors are also included in the analysis. The data were derived from Mine Safety and Health Administration (MSHA) mine fire accident publications and verbal communications with mine personnel. The analysis will provide the National Institute for Occupational Safety and Health, MSHA, and the mining industry with a better understanding of the causes and hazards associated with mine fires and an increased awareness aimed at preventing and reducing fire hazards. It will also form a basis for future fire research programs.

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INTRODUCTION

Mine fires pose a constant danger to the safety of miners and to their livelihood. Underground mine fires pose an added hazard because of the confined environment with remote exits. Enactment of safety regulations [30 CFR[2] 56, 57] for underground and surface metal/nonmetal operations has greatly improved the safety of miners. However, mine fires and fire injuries remain serious hazards for all underground and surface mines.

This report analyzes mine fires and fire injuries for all U.S. metal/nonmetal mining categories, including sand and gravel and stone operations, during 1990–2001. Fires involving contractors are also included in the analysis. A similar analysis of fire incidents in metal/nonmetal mines during 1950–1984 was done by the former U.S. Bureau of Mines (USBM) [Butani and Pomroy 1987]. Detailed analyses of mobile equipment fires for all underground and surface coal and metal/nonmetal mining categories during 1990–1999 have recently been reported by NIOSH [De Rosa 2004].

Injury risk rate (Irr) values for the 12-year time period (1990–2001) and for six successive 2-year time periods within the 12-year period are derived. Irr values for individual states for the 12-year period are also derived. Other variables by state and time period include employees' working hours and lost workdays. The number of fire fatalities is reported by time period. Variables such as ignition source, method of detection and suppression, equipment involved, location, and burning material are reported by six 2-year time periods only. Furthermore, the number of fire injuries per number of fires causing injuries and total fires has been analyzed by year, ignition source, equipment involved, and location. For comparison purposes, the major fire and fire injury findings for all metal/nonmetal mining categories have been reported.

The data in this report were derived from "Injury Experience" publications [MSHA 1991a,b,c,d; 1992a,b,c,d; 1993a,b,c,d; 1994a,b,c,d; 1995a,b,c,d; 1996a,b,c,d; 1997a,b,c,d; 1998a,b,c,d; 1999a,b,c,d; 2000a,b,c,d; 2001a,b,c,d; 2002a,b,c,d], "Fire Accident Reports" [MSHA 1993e; 1994e; 1995e; 1996e; 1997e,f; 2000e], MSHA "Fire Accident Abstracts" internal publications, and verbal communications with mine personnel. Mining companies are required by 30 CFR 50 to report to MSHA all fires that result in injuries and fires that are not extinguished within 30 min of discovery. A small number of fires lasting <30 min without injuries reported in the "Fire Accident Abstracts" have been included in this report. Also included in this report are fires caused by explosions and explosives.

The analysis in this report will provide the National Institute for Occupational Safety and Health (NIOSH), the Mine Safety and Health Administration (MSHA), and the mining industry with a better understanding of the causes and hazards of mine fires and fire injuries and an increased awareness aimed at preventing and reducing fire hazards. It will also form a basis for developing future fire research programs.

METHODOLOGIES

For all metal/nonmetal mining categories, data on mine fires during 1990–2001 have been reported as actual numbers and calculated values.

1. For each mining category, actual numbers include the total number of fires, fire injuries, employees' working hours, and lost workdays for a 12-year period (1990–2001) and for six successive 2-year periods within the 12-year period. These numbers have also been reported by state for the 12-year time period. The actual number of fire fatalities has been reported by time period. Furthermore, actual numbers of fires for the six 2-year periods have been reported by ignition source, method of detection and suppression, equipment involved, location, and burning material. Actual numbers of fire injuries per number of fires causing injuries and total fires have been reported by year, ignition source, equipment involved, and location.

2. For each mining category, the calculated values include the injury risk rates during the 12-year period and the six 2-year periods. The injury risk rate (Irr) values were calculated according to the MSHA formula (incidence rate (IR) = number of fire injuries × 200,000 working hours divided by the total employees' working hours) [MSHA 1991a,b,c,d; 1992a,b,c,d; 1993a,b,c,d; 1994a,b,c,d; 1995a,b,c,d; 1996a,b,c,d; 1997a,b,c,d; 1998a,b,c,d; 1999a,b,c,d; 2000a,b,c,d; 2001a,b,c,d; 2002a,b,c,d]. Also, injury risk rate values for individual states (12-year period) were calculated according to this same formula.

For comparison purposes, only the injury risk rate values for 12-year and 2-year time periods and the injury risk rate values for individual states (12-year time period) with the highest number of fire injuries have been considered. The fatality risk rate values have not been calculated because of the small number of fatalities that occurred during the 12-year period.

3. Calculations of Irr values are as follows:

a. Injury risk rate (Irr) value: Number of fire injuries × 200,000 working hours divided by total employees' working hours. The Irr value is the average risk rate value for the number of fire injuries per 200,000 working hours for a given time period.

b. Total employees' working hour (Ewhr) value during 1990–2001: Sum of 12 yearly Ewhr values for all of the

[2] *Code of Federal Regulations*. See CFR in references.

states involved in fires. This value also includes the Ewhr value reported for all other states not involved in fires. The Ewhr value for each state (12-year time period) is the sum of 12 yearly Ewhr values for that state.

c. Total employees' working hours (Ewhr) value for six 2-year time periods: Sum of two yearly Ewhr values for all of the states involved and not involved in fires within the 2-year period.

d. The lost workday (LWD) values were reported by state and time period.

e. A lost workday value of 6,000, assigned by MSHA to each fatality or permanent total disability, was reported.

FIRE DATA ANALYSIS FOR ALL METAL/NONMETAL MINING CATEGORIES

UNDERGROUND METAL/NONMETAL AND STONE MINE FIRES

Table 1 and figure 1 show the number of fires and fire injuries that occurred in underground metal/nonmetal and stone mines by state during 1990–2001. Table 1 also shows the injury risk rates, employees' working hours, and lost workdays. Overall, 65 fires occurred in 20 states; these include 2 fires and no injuries for contractors. Six of the fires caused nine injuries. The yearly average was 5.4 fires and 0.75 injury. Forty-one fires with 2 injuries occurred in metal mines, 14 fires with 7 injuries occurred in nonmetal mines, and 10 fires with no injuries occurred in stone mines. The underground mine fires required 25 mine rescue team interventions and 30 mine/section evacuations. The Ewhr value was 260×10^6 hr (Irr = 0.007), and the LWD value was 83.

Idaho had the most fires (eight fires and no injuries), followed by Louisiana (seven fires and two injuries), Michigan (six fires and six injuries), and Missouri (six fires and no injuries). Of these states, Michigan had the highest injury risk rate value (Irr = 0.146).

Table 2, partly illustrated in figure 2, shows the number of fires, fire injuries, risk rates, employees' working hours, and lost workdays by time period. The number of fires during the six time periods show an increase during the fourth period followed by a sharp decrease during the fifth period and a sharp increase in the last period. The number of fire injuries show an increase followed by a decrease during most of the periods, accompanied by a decline in employees' working hours during most of the periods; an increase is seen during the third and fourth periods. The Irr values follow patterns similar to those shown by the injury values.

Tables 3–8 show the number of fires by ignition source, method of detection and suppression, equipment involved, location, and burning material by time period. Figure 3 shows the major variables related to fires for 1990–2001. Table 9 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location.

Ignition Source

Table 3 shows the number of fires by ignition source for each time period. The sources that caused most of the underground metal/nonmetal and stone mine fires were hydraulic fluid/fuel sprayed onto equipment hot surfaces (16 fires or 25%), flame cutting/welding spark/slag/flame (13 fires or 20%), and electrical short/arcing (12 fires or 19%).

Thirteen of the 16 mobile equipment hydraulic fluid/fuel fires became large fires because of the continuous flow of fluids from the pumps due to engine shutoff failure, lack of an emergency line drainage system, or lack of effective and rapid local firefighting response capabilities. In at least two instances during these fires, the cab was suddenly engulfed in flames, probably due to the ignition of flammable vapors and mists that penetrated the cab. Of note is that the hydraulic fluid fires subsequently involved the fuel system. Other ignition sources included engine/motor mechanical malfunctions, spontaneous combustion (involving timber)/hot material, conveyor belt/equipment friction, heat source (mostly involving heaters), overheated oil, and explosion/ignition of explosives. Fires caused by the spontaneous combustion/hot material and electrical short/arcing ignition sources were usually detected long after they had started due to lack of combustion gas/smoke detection systems.

During the first period, the largest number of fires were caused by hydraulic fluid/fuel sprayed onto equipment hot surfaces, flame cutting/welding spark/slag/flame, and electrical short/arcing sources. During the second period, the largest number of fires were caused by flame cutting/welding spark/slag/flame and electrical short/arcing sources. During the third period, the largest number of fires were caused by conveyor belt/equipment friction. During the fourth period, the largest number of fires were caused by hydraulic fluid/fuel sprayed onto equipment hot surfaces. During the fifth period, the largest number of fires were caused by hydraulic fluid/fuel sprayed onto equipment hot surfaces and flame cutting/welding spark/slag/flame. During the sixth period, the largest number of fires were caused by hydraulic fluid/fuel.

Method of Detection

Table 4 shows the number of fires by method of detection for each time period. The most frequent methods were miners who saw smoke long after the fire had started, operators who saw the fires when they started as flames/flash fires, and miners who saw smoke shortly after the fires had started. Other methods of detection were welders who saw sparks, miners who heard an explosion or smelled smoke, and operators who experienced an equipment power loss. One fire was detected by carbon monoxide gas sampling, and two fires were undetected.

During the first period, the largest number of fires were detected by operators as flames/flash fires. During the second period, the largest number of fires were detected by welders as sparks. During the third, fifth, and sixth periods, the largest number of fires were detected by miners as smoke long after the fires had started. During the fourth period, the largest number of fires were detected visually as flames and sparks.

Table 1.—Number of fires, fire injuries, and risk rates for underground metal/nonmetal and stone mines by state, employees' working hours, and lost workdays, 1990–2001

State[1]	No. fires[1]	No. fire injuries[1]	LWD[2]	Ewhr,[2] 10^6 hr	Irr[3]
Alaska	1	—	—	2	—
Arizona	3	—	—	28.3	—
Colorado	3	—	—	9.6	—
Idaho	8	—	—	9.7	—
Illinois	2	—	—	0.5	—
Indiana	2	—	—	2.1	—
Kansas	1	—	—	1	—
Kentucky	2	—	—	11.3	—
Louisiana	7	2	24	7.4	0.054
Michigan	6	6	52	8.2	0.146
Missouri	6	—	—	16.8	—
Montana	2	—	—	10.5	—
Nevada	3	—	—	14	—
New Mexico	4	—	—	22.8	—
New York	5	—	—	9.4	—
Ohio	2	—	—	5.7	—
South Dakota	3	—	—	12.1	—
Tennessee	1	—	—	14	—
Washington	1	—	—	3	—
Wyoming	3	1	7	24.5	0.008
All other states	—	—	—	47	—
Total	65	9	83	260	[3]0.007

[1]Derived from MSHA "Fire Accident Abstract" internal publications.
[2]Derived from MSHA "Injury Experience in Mining" publications.
[3]Calculated according to MSHA formula reported in the "Methodologies" section.

Table 2.—Number of fires, fire injuries, and risk rates for underground metal/nonmetal and stone mines by time period, employees' working hours, and lost workdays, 1990–2001

	Time period						
	90-91	92-93	94-95	96-97	98-99	00-01	1990-2001
Number of fires[1]	10	10	10	15	6	14	65
Number of fire injuries[1]	1	3	—	5	—	—	9
LWD[2]	2	31	—	50	—	—	83
Ewhr,[2] 10^6 hr	49	42	43	45	41	40	260
Irr[3]	0.004	0.014	—	0.022	—	—	[3]0.007

[1]Derived from MSHA "Fire Accident Abstract" internal publications.
[2]Derived from MSHA "Injury Experience in Mining" publications.
[3]Calculated according to MSHA formula reported in the "Methodologies" section.

Table 3.—Number of fires for underground metal/nonmetal and stone mines by ignition source and time period, 1990–2001

Ignition source	Time period						
	90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	00-01 No. fires	1990-2001 No. fires
Hydraulic fluid/fuel on equipment hot surfaces	2	2	2	4	2	4	16
Flame cutting/welding spark/slag/flame	2	3	2	3	2	1	13
Electrical short/arcing	2	3	1	1	1	4	12
Engine/motor malfunction	—	1	—	3	—	1	5
Conveyor belt/equipment friction	—	—	3	2	—	—	5
Spontaneous combustion (involving timber)/ hot material	1	1	—	—	—	3	5
Heat source	1	—	1	—	1	1	4
Explosion/ignition-explosives	1	—	1	—	—	—	2
Overheated oil	—	—	—	2	—	—	2
Unknown	1	—	—	—	—	—	1
Total	10	10	10	15	6	14	65

Table 4.—Number of fires for underground metal/nonmetal and stone mines by method of detection and time period, 1990–2001

Method of detection	Time period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	00-01 No. fires	1990-2001 No. fires
Visual:							
Late smoke detection	1	2	4	2	3	6	18
Flames/flash fires	3	2	3	3	2	4	17
Sparks	2	3	1	3	1	—	10
Heard explosion	1	—	1	—	—	—	3
Smelled smoke	—	1	—	—	—	1	2
Power loss	—	1	—	—	—	—	1
CO gas sampling	—	1	—	—	—	—	1
Undetected	2	—	—	—	—	—	2
Total	10	10	10	15	6	14	65

Table 5.—Number of fires for underground metal/nonmetal and stone mines by suppression method and time period, 1990–2001

Suppression method	Time period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	00-01 No. fires	1990-2001 No. fires
FE-DCP-foam-water	2	4	2	3	3	9	23
Water	3	3	2	4	3	3	18
Portable fire extinguisher	3	2	1	6	—	2	14
FSS-DCP-foam-water	—	1	1	—	—	—	2
FSS-HD[1]	—	—	1	1	—	—	2
Manual with FE[2]	—	—	1	—	—	—	1
Destroyed/HD[3]	2	—	2	1	—	—	5
Total	10	10	10	15	6	14	65

DCP Dry chemical powder.
FE Portable fire extinguisher.
FSS Machine fire suppression system.
HD Heavily damaged.
[1]Heavy damage to equipment due to FSS activation failure or late activation.
[2]Method used by welders to extinguish clothing and oxyfuel/grease fires.
[3]Usually due to failure of other firefighting methods, late fire detection, undetected fires, or fire size.

Table 6.—Number of fires for underground metal/nonmetal and stone mines by equipment involved and time period, 1990–2001

Equipment	Time period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	00-01 No. fires	1990-2001 No. fires
Mobile equipment[1]	3	5	4	9	3	7	31
Oxyfuel torch[2]	2	3	1	2	2	—	10
Beltline	—	—	3	1	—	1	5
Electrical system/battery/charger	1	1	—	—	—	3	5
Heater/cutting saw	1	—	—	1	1	1	4
Explosive box	1	—	1	—	—	—	2
Air compressor	—	—	—	2	—	—	2
Other[3]	2	1	1	—	—	2	6
Total	10	10	10	15	6	14	65

[1]Includes golf and ore carts, locomotives, loaders, scoops, tractors, shuttle cars, power scalers, trolleys, trucks, and drills.
[2]At times, electrical arc welding equipment was used.
[3]Did not involve equipment.

Table 7.—Number of fires for underground metal/nonmetal and stone mines by location and time period, 1990–2001

Location	Time period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	00-01 No. fires	1990-2001 No. fires
Mobile equipment working areas[1]	3	4	2	6	1	4	20
Flame cutting/welding areas[2]	2	3	2	3	2	1	13
Mine face/section/crosscut/drift areas	2	2	—	2	—	1	7
Battery/motor barn/pipeline areas	1	—	1	1	1	2	6
Belt entry	—	—	3	1	—	1	5
Shop/refuse/maintenance areas	1	—	—	—	1	2	4
Chute/crusher/air compressor areas	—	—	1	1	—	1	3
Decline slopes	—	1	—	—	1	1	3
Gobline/abandoned areas	1	—	—	—	—	1	2
Panel/tunnel areas	—	—	1	1	—	—	2
Total	10	10	10	15	6	14	65

[1]Includes haulage, loading, mucking, transportation, and drilling areas.
[2]Includes shops, mainways, boreholes, shafts, stations, slusher buckets and chute areas, and mobile equipment maintenance areas.

Table 8.—Number of fires for underground metal/nonmetal and stone mines by burning material and time period, 1990–2001

Burning material	Time period 90-91 No. fires	92-93 No. fires	94-95 No. fires	96-97 No. fires	98-99 No. fires	00-01 No. fires	1990-2001 No. fires
Hydraulic fluid/fuel	2	2	2	4	2	4	16
Electrical cord/cables/wires/batteries	3	3	1	1	1	4	13
Oxyfuel/clothing/grease/other[1]	2	3	2	3	2	1	13
Belt material	—	—	3	2	—	1	6
Refueling fuel/flammable liquid/oil/ grease/refuse	2	—	1	2	1	—	6
Timber/pipeline/chute liner	—	1	—	—	—	3	4
Equipment mechanical components	—	1	—	3	—	—	4
Detonated explosives	1	—	1	—	—	—	2
Shop/content	—	—	—	—	—	1	1
Total	10	10	10	15	6	14	65

[1]Includes rubber tires and hoses, refuse, chute liner, hydraulic fluid, shop, wood, and shaft material.

Table 9.—Number of fire injuries per number of fires causing injuries and total fires for underground metal/nonmetal and stone mines by year, ignition source, equipment involved, and location, 1990–2001

Year	No. total fires	No. fires causing injuries	No. fire injuries	Ignition source	Equipment	Location
1990	3	1	1	Hydraulic fluid/fuel on equipment hot surfaces	Ore cart	Transportation area.
1991	7	—	—	—	—	—
1992	6	2	1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.
			1	Overheated oil	Scoop	Mining area.
1993	4	1	1	Flame cutting/welding spark/slag/flame	Oxyfuel torch	Flame cutting/welding areas.
1994	8	—	—	—	—	—
1995	2	—	—	—	—	—
1996	6	1	1	Overheated oil	Air compressor	Drilling area.
1997	9	1	4	Hydraulic fluid/fuel on equipment hot surfaces	Scoop	Mining area.
1998	3	—	—	—	—	—
1999	3	—	—	—	—	—
2000	8	—	—	—	—	—
2001	6	—	—	—	—	—
Total	65	6	9			

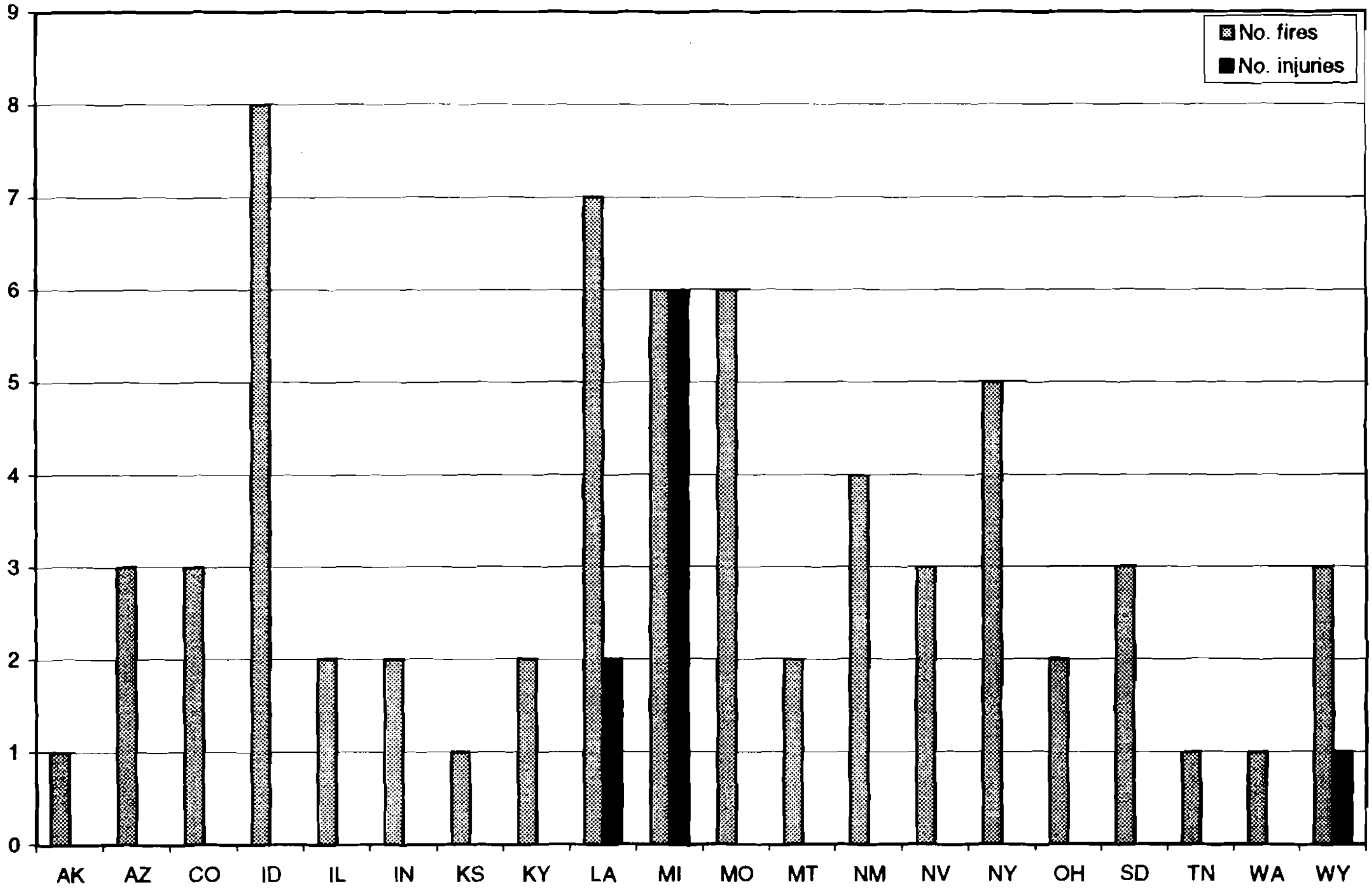

Figure 1.—Number of fires and fire injuries for underground metal/nonmetal and stone mines by state, 1990–2001.

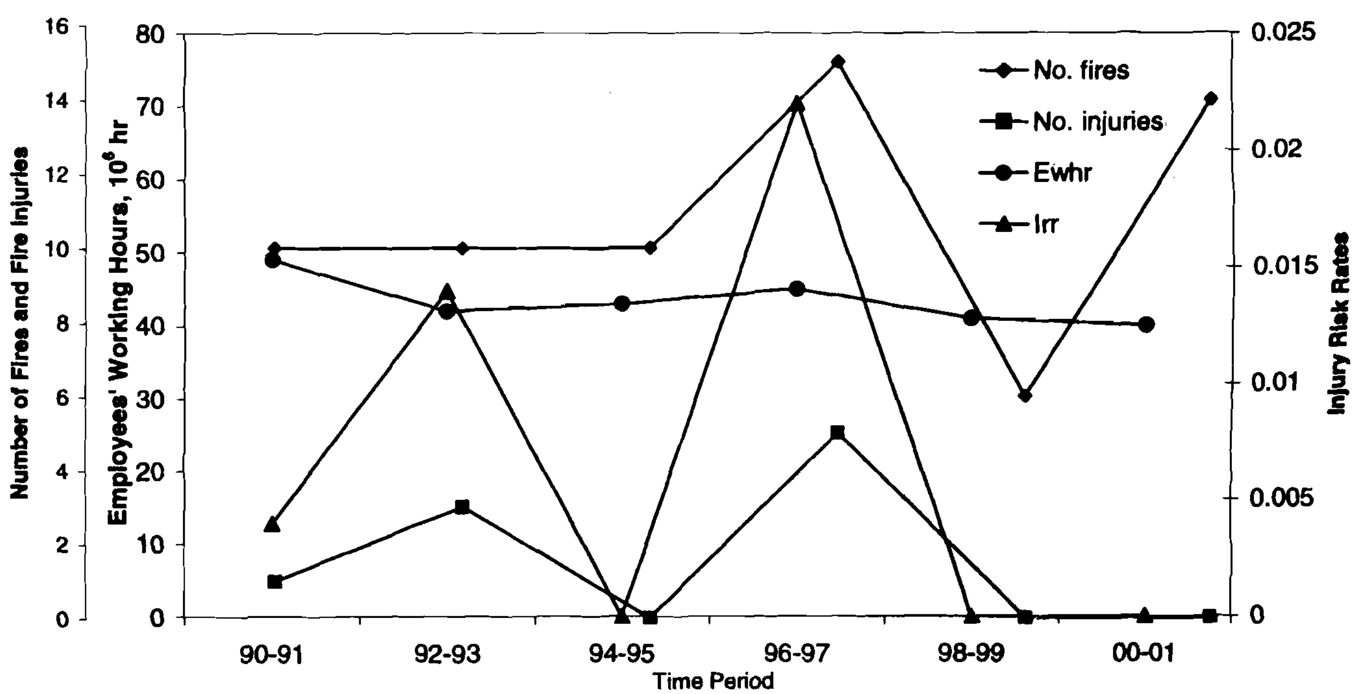

Figure 2.—Number of fires, fire injuries, risk rates, and employees' working hours for underground metal/nonmetal and stone mines by time period, 1990–2001.

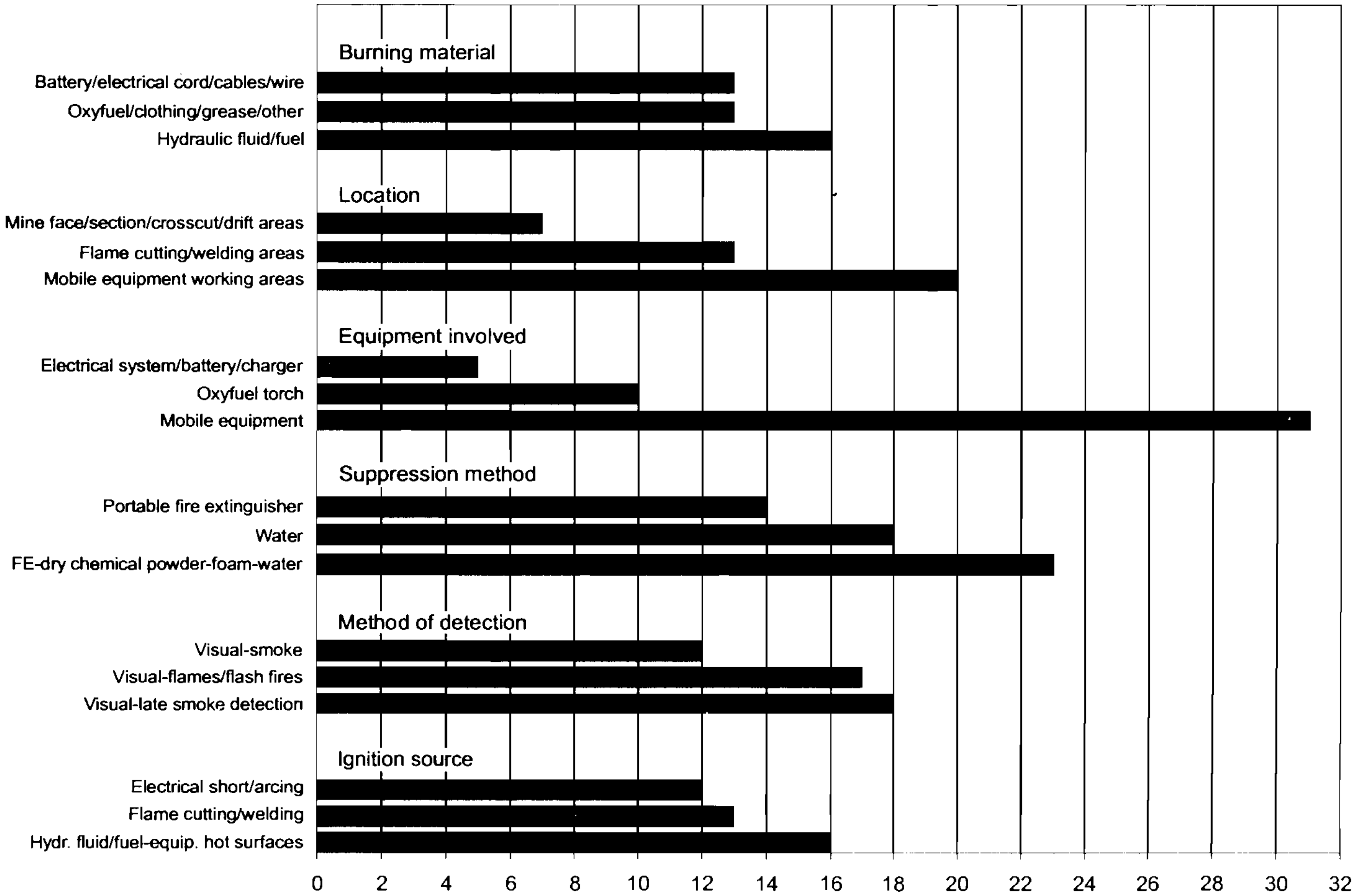

Figure 3.—Major variables for underground metal/nonmetal and stone mine fires, 1990–2001. (FE = portable fire extinguisher)

Suppression Method

Table 5 shows the number of fires by suppression method for each time period. Usually more than one agent was used to fight a fire. The most common methods were portable fire extinguishers with dry chemical powder, foam, and water, followed by water or portable fire extinguishers alone. Other suppression methods included machine fire suppression systems with dry chemical powder, foam, and water and manual techniques with or without portable fire extinguishers (welders' method to extinguish clothing and oxyfuel/grease fires). Four of the 16 pieces of mobile equipment involved in hydraulic fluid/fuel fires had machine fire suppression systems. Dual activations (two activations) of machine fire suppression and engine shutoff systems succeeded in temporarily abating the fires; however, the flames reignited, fueled by the flow of pressurized fluids entrapped in the lines. On one occasion the fire suppression system failed to activate, and in another instance the system was activated late.

Portable fire extinguishers, used upon discovery of the fires, were successful in extinguishing small fires involving oxyfuel/grease, oil, refueling fuel, and electrical wires, cables and batteries. Mine rescue teams (required 25 times), upon mine/section evacuation (performed 30 times), fought the fires (including 12 mobile equipment fires) with dry chemical powder and water; in one instance, foam was also used. However, seven fires destroyed or heavily damaged equipment (including four pieces of mobile equipment) because of failure of firefighting methods, late fire detection, undetected fires, or fire size. Other factors that determined the success of fire suppression efforts were the time lapse between detection and application of extinguishing agents and effective and rapid local firefighting response capabilities.

During the first period, the largest number of fires were suppressed with portable fire extinguishers or water alone. During the second and sixth periods, the largest number of fires were suppressed with portable fire extinguishers together with dry chemical powder, foam, and water. During the third and fifth periods, the largest number of fires were suppressed with water alone and portable fire extinguishers with dry chemical powder, foam, and water. During the fourth period, the largest number of fires were suppressed with portable fire extinguishers alone.

Equipment Involved

Table 6 shows the number of fires by equipment involved for each time period. The equipment most often involved was mobile equipment (golf and ore carts, locomotives, shuttle cars, loaders, power scalers, scoops, tractors, trolleys, trucks, and drills), followed by oxyfuel torches (at times electrical arc welding equipment was used). Other equipment included belt-lines, electrical systems, batteries, chargers, heaters, cutting saws, explosive boxes, and air compressors. Six fires did not involve equipment. During all of the periods, the largest number of fires involved mobile equipment.

Location

Table 7 shows the number of fires by location for each time period. The most common locations were mobile equipment working areas (haulage, loading, mucking, transportation and drilling areas, decline slopes), followed by flame cutting/welding areas (at shops, mainways, boreholes, shafts, stations, slusher bucket and chute areas, and maintenance areas), and mine face, section, crosscut, and drift areas. Other fire locations were battery and pipeline areas, motor barns, belt entries, shops, refuse and maintenance areas, decline slopes, chute and crusher areas, panel and tunnel areas, and goblines and abandoned areas.

During the first, second, fourth, and sixth periods, the largest number of fires occurred at mobile equipment working areas. During the third period, the largest number of fires occurred at belt entries. During the fifth period, the largest number of fires occurred at flame cutting/welding areas.

Burning Materials

Table 8 shows the number of fires by burning material for each time period. The materials most often involved were hydraulic fluid/fuel, electrical cord, cables, wires, batteries, oxyfuel/clothing/grease, and materials such as rubber tires and hoses, hydraulic fluid, shop, refuse, wood, chute liner, and shaft material. Other burning materials included belt material, re-fueling fuel, flammable liquids, oil, grease, refuse, timber, pipe-lines, chute liners, equipment mechanical components, deto-nated explosives, and shops and their content.

During the first period, the largest number of fires involved electrical cord, cables, wires, and batteries. During the second period, the largest number of fires involved oxyfuel, clothing/grease, and other materials and electrical cord, cables, wires, and batteries. During the third period, the largest number of fires involved belt materials. During the fourth period, the largest num-ber of fires involved hydraulic fluid/fuel. During the fifth period, the largest number of fires involved hydraulic fluid/fuel and oxyfuel. During the sixth period, the largest number of fires involved hydraulic fluid/fuel and electrical materials.

Fire Injuries

Table 9 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location during 1990–2001. Overall, there were nine injuries caused by six fires. The greatest number of fire injuries occurred in 1997 (four injuries caused by one fire). The ignition sources that caused the fire injuries were hydraulic fluid/fuel sprayed onto equipment hot surfaces, flame cutting/welding spark/slag/flame, and overheated oil. The equipment involved in fire injuries included mobile equipment, oxyfuel torches, and air compressors. The locations where the fire injuries occurred were mobile equipment working areas, flame cutting/welding areas, and mining areas.

SURFACE OF UNDERGROUND METAL/NONMETAL AND STONE MINE FIRES

Table 10 and figure 4 show the number of fires and fire injuries occurring at the surface of underground metal/nonmetal and stone mines by state during 1990–2001. Table 10 also shows the injury risk rates, employees' working hours, and lost workdays.

A total of 12 fires occurred in 11 states; 5 of the fires caused 5 injuries. The yearly average was one fire and 0.42 injury. Five fires with two injuries occurred at metal mines, five fires with two injuries occurred at nonmetal mines, and two fires with one injury occurred at stone mines. None of the fires involved contractors. The Ewhr value was 58×10^6 hr (Irr = 0.017), and the LWD value was 75.

Nevada had the most fires (two fires and no injuries). Ohio, New Mexico, Missouri, South Dakota, and Idaho each had one fire with one injury. Of these states, Missouri had the highest injury risk rate value (Irr = 0.25).

Table 11, partly illustrated in figure 5, shows the number of fires, fire injuries, risk rates, employees' working hours, and lost workdays by time period. The number of fires decreased during most of the six time periods. The number of fire injuries and employees' working hours decreased during all of the periods. The Irr values follow patterns similar to those shown by the injury values.

Tables 12–17 show the number of fires by ignition source, method of detection and suppression, equipment involved, location, and burning material by time period. Figure 6 shows the major variables related to fires for 1990–2001. Table 18 shows the number of fire injuries per number of fires causing injuries and total fires by year, ignition source, equipment involved, and location.

Ignition Source

Table 12 shows the number of fires and fire injuries by ignition source for each time period. The leading source was flame cutting/welding spark/slag/flame (seven fires or 58%), followed by electrical short/arcing and heat source (one fire for each ignition). The ignition sources for three fires were unknown.

During the first through third periods, the fires were caused by the flame cutting/welding spark/slag/flame source. During the fifth period, the fire was caused by a heat source. During the